Geological Survey
of Canada

Current Research
2000-C19

Granite-greenstone relationships at the southern Sturgeon belt margin in the Brightsand forest area, Ontario

J.L. Brown, J.A. Percival, D. White, K.Y. Tomlinson, and V. McNicoll

2000

Natural Resources Canada | Ressources naturelles Canada

Canada

Catalogue No. M44-2000/C19E-IN
ISBN 0-660-18038-3

Available in Canada from the
Geological Survey of Canada Bookstore website at:
http://www.nrcan.gc.ca/gsc/bookstore (Toll-free: 1-888-252-4301)

A copy of this publication is also available for reference by depository libraries across Canada through access to the Depository Services Program's website http://dsp-psd.pwgsc.gc.ca. A list of these libraries can be consulted at this site or obtained by calling the toll-free number above.

Price subject to change without notice

Authors' addresses

J.L. Brown *(julbrown@NRCan.gc.ca)*
Department of Earth Sciences
University of Ottawa
Ottawa, Ontario K1N 6N5

J.A. Percival *(joperci@NRCan.gc.ca)*
D. White *(dowhite@NRCan.gc.ca)*
K.Y. Tomlinson *(ktomlins@NRCan.gc.ca)*
V. McNicoll *(vmcnicol@NRCan.gc.ca)*
Continental Geoscience Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

Granite-greenstone relationships at the southeastern Sturgeon belt margin in the Brightsand forest area, Ontario[1]

J.L. Brown, J.A. Percival, D. White, K.Y. Tomlinson, and V. McNicoll
Continental Geoscience Division, Ottawa

Brown, J.L., Percival, J.A., White, D., Tomlinson, K.Y., and McNicoll, V., 2000: Granite-greenstone relationships at the southeastern Sturgeon belt margin in the Brightsand forest area, Ontario; Geological Survey of Canada, Current Research 2000-C19, 10 p. (online; http://www.nrcan.gc.ca/gsc/bookstore)

Abstract: At the southeastern margin of the Sturgeon Lake–Savant Lake greenstone belt, screens of amphibolite-facies supracrustal rocks, separated by plutonic and gneiss units, mark the interface between volcanic rocks of the western Wabigoon and granitoid rocks-gneiss of the central Wabigoon Subprovince. Complex tonalite gneiss records D_1 and D_2 events not present in supracrustal and other plutonic units which sustained regional D_3 and D_4 deformation. The complex gneiss may represent depositional basement to supracrustal rocks correlative with the continental margin sequence of the Sturgeon–Savant belt. Alternatively, the fold geometry of this unit can be explained by large-scale fold interference. The steeply north-dipping Hilltop Creek and Robert Lake faults, which appear on LITHOPROBE seismic line 1d as steep truncations, separate the region into metamorphically and lithologically distinct structural panels. The faults are spatially and probably mechanically related to the sinistral Wapikamaiski Lake and Brightsand River shear zones.

Résumé : Le long de la marge sud-est de la ceinture de roches vertes de Sturgeon Lake–Savant Lake, des lambeaux de roches supracrustales du faciès des amphibolites, séparés par des unités plutoniques et gneissiques, marquent l'interface entre les roches volcaniques de la partie occidentale de la Sous-province de Wabigoon et les gneiss et roches granitoïdes de la partie centrale de cette sous-province. Un gneiss tonalitique complexe témoigne d'événements D_1 et D_2 qui ne sont présents ni dans les roches supracrustales ni dans les autres unités plutoniques ayant subi des déformations régionales D_3 et D_4. Le gneiss complexe peut représenter le socle sur lequel se sont déposées les roches supracrustales qui sont corrélées avec la séquence de marge continentale de la ceinture de Sturgeon Lake–Savant Lake. La géométrie des plis dans cette unité peut également être attribuée à une interférence à grande échelle due aux plis. Les failles de Hilltop Creek et de Robert Lake, à fort pendage vers le nord, qui prennent la forme de troncatures escarpées sur la ligne sismique LITHOPROBE 1d, séparent la région en panneaux stucturaux aux régimes métamorphiques et aux lithologies distincts. Les failles sont associées spatialement et probablement mécaniquement aux zones de cisaillement senestres de Wapikamaiski Lake et de Brightsand River.

[1] Contribution to Western Superior NATMAP Project

INTRODUCTION

The Wabigoon Subprovince can be subdivided into three parts (Blackburn et al., 1991). The eastern and western Wabigoon are made up of isolated and interconnected Neoarchean greenstone belts, respectively, whereas the central Wabigoon consists mainly of granitoid and gneissic units including relics of Mesoarchean crust (Percival et al., 1999a). The nature of the contacts between these major components of the Wabigoon Subprovince is cryptic; neither unconformities nor tectonic contacts between Mesoarchean and Neoarchean rocks have been observed directly.

Screens of supracrustal rocks extend from the Sturgeon Lake–Savant Lake greenstone belt into the central Wabigoon region in the Brightsand forest area, providing the opportunity to study the boundary zone between juvenile volcanic rocks and evolved crystalline rocks of the central Wabigoon (Percival et al., 1999b). A central goal of the Western Superior NATMAP Project is to understand the tectonic versus depositional nature of such contacts at a regional scale. This project focuses on a key area (enclosed box, Fig. 1) defined in recent studies in the vicinity of the eastern Sturgeon Lake belt (Percival et al., 1999a; Sanborn-Barrie and Skulski, 1999). Specifically, the relationship between amphibolite-facies supracrustal remnants and the various gneissic and plutonic units which separate them, is being examined through 1:20 000 mapping, complemented by metamorphic and geochronological studies. Correlation based on geochemical and lithological similarity is made with lower metamorphic grade, less metasomatized rocks of the Sturgeon–Savant belt to the west. The area was imaged in Western Superior LITHOPROBE line 1D, providing information from the third dimension to constrain structural relationships between supracrustal and granitoid packages observed in the field.

Regional geological setting

The study area is located in the boundary zone between the central and western Wabigoon Subprovince in the Brightsand forest area (enclosed box, Fig. 1). To the west, the Sturgeon–Savant greenstone belt has three distinct stratigraphic packages, a continental margin sequence (Jutten group), a diverse oceanic terrane (Beckington, central Sturgeon, and south Sturgeon sequences), and a polymictic conglomerate-turbidite succession (Savant sedimentary group) that marks the interface between the two (Sanborn-Barrie and Skulski, 1999). The continental margin sequence contains diagnostic basal quartz-rich clastic rocks, inferred to have been deposited upon Mesoarchean continental basement on the basis of detrital zircons dated between 2948 ± 3 Ma and

Figure 1. Location map. The eastern Wabigoon lies approximately 50 km to the east of the map boundary. The box encloses the study area between the Wapikaimaski Lake and the Brightsand River D_4 shear zones. The D_3 Gunter Lake shear zone is overprinted by the Brightsand River shear zone within the study area.

3199 ± 3 Ma (Sanborn-Barrie and Skulski, 1999). Oceanic rocks were formed outboard from 2775 Ma to 2718 Ma (Sanborn-Barrie and Skulski, 1999). The turbiditic succession is interpreted to record a collisional, possibly suturing event at ca. 2700 Ma. The granitoid rocks-gneiss complex of the central Wabigoon Subprovince to the east is made up of several generations of plutonic rocks and older gneiss units (Percival et al., 1999a). Up to four sets of structures are recognized within some tonalite gneiss packages, two of which (D_1, D_2) appear older than supracrustal rocks at the regional scale. These older structures include S_1 layering folded into F_2 folds. D_3 and D_4 structures within granitoid rocks, including a regional S_3 foliation and upright map-scale F_4 folds, correlate with D_1 and D_2 fabric elements within the Sturgeon–Savant belt (Percival et al., 1999a, Sanborn-Barrie and Skulski, 1999).

DESCRIPTION OF MAP UNITS

The map area (Fig. 2) can be divided into three structural panels on the basis of lithological, structural, and metamorphic character, and the presence of brittle-ductile deformation zones. From south to north, the size and volume of supracrustal units decrease, whereas metamorphic grade and the volume of granitic intrusions increase. Units of supracrustal origin rarely preserve primary structures and carry two generations of deformation fabrics, a penetrative regional S_3 foliation, and F_4 folds and lineations (Percival et al., 1999a).

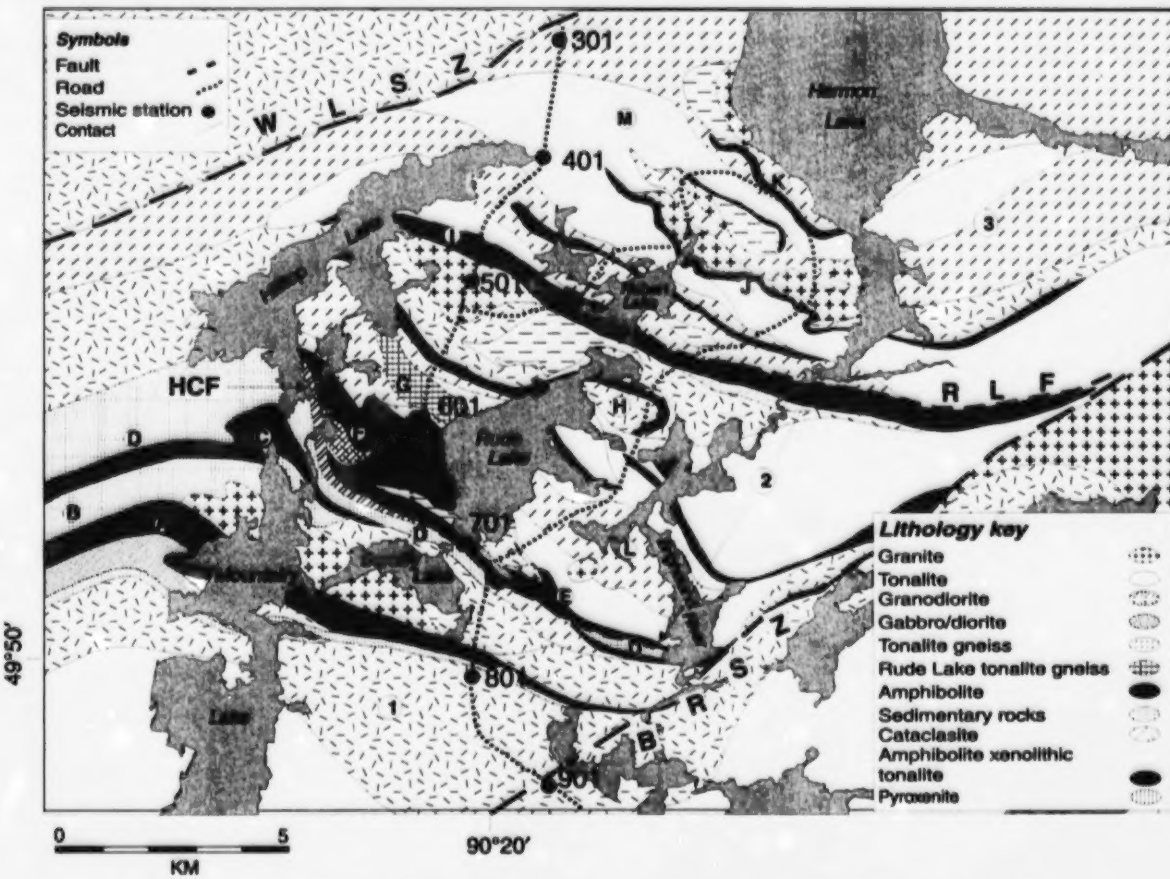

Figure 2. Geology map of the Brightsand forest area including seismic station locations, large lakes, and map units discussed in the text. A = Mountairy Lake supracrustal unit; B = southern sedimentary unit; C = Hilltop Lake supracrustal unit; D = northern sedimentary unit; E = Scruffy Lake supracrustal unit; F = Rude Lake supracrustal unit; G = Rude Lake tonalite gneiss; H = Brightsand River supracrustal unit; I = Robert Lake supracrustal unit; J = Stinson Lake supracrustal unit; K = northern supracrustal unit; L = pyroxenite; M = S_2-foliated tonalite; BRSZ = Brightsand River shear zone; WLSZ = Wapikaimaski Lake shear zone; RLF = Robert Lake fault; HCF = Hilltop Creek fault; 1 = southern structural panel; 2 = central structural panel; 3 = northern structural panel.

Southern structural panel

The east-northeast-trending, sinistral Brightsand River D_4 shear zone (Fig. 2; Percival et al., 1999a) bounds the southern structural panel in the southeastern corner of the map area. Mylonitic granodiorite and L>S syntectonic granite with subhorizontal stretching lineations characterize this deformation zone. Amphibolite units appear to warp into this shear zone but cannot be traced east of the structure.

Supracrustal rocks

The Mountairy Lake and Hilltop Lake supracrustal units ('A' and 'C', Fig. 2) consist of amphibolite, interpreted as metamorphosed basalt and andesite based on fine grain-size and local heterogeneities. Within the Mountairy Lake unit, dykes and sills of gabbro are common, and sporadic greywacke layers occur within the metavolcanic rocks of this package. Rare layers of garnet-bearing felsic volcanic rocks, up to 2.5 m thick, are present within amphibolite in the hinge of a map-scale fold in northern Mountairy Lake. Common mineral assemblages in metavolcanic rocks are epidote-actinolite-plagioclase with minor garnet and chlorite within gabbroic and andesitic compositions.

The Hilltop Lake unit is bound to the south and north by sedimentary rocks ('B' and 'D', Fig. 2). The southern sedimentary package consists of sandstone and greywacke, and is interlayered with metavolcanic rocks of the Hilltop Lake unit. The northern sedimentary unit is a diverse panel that contains greywacke, quartz-rich sandstone, slate, granitoid-clast conglomerate, and silicate-facies iron-formation. Sandstone units can be traced up to 7.5 km along strike. Graded and laminar bedding is preserved locally, and generally transposed into the dominant S_3 foliation. Based on the continuity of these units along strike to the west of the study area (Rogers, 1964) and similar rock associations, the southern and northern sedimentary units are correlated with the Post Lake and Quest Lake groups respectively (Trowell, 1983) associated with the diverse oceanic terrane and the Savant sedimentary group in the Sturgeon–Savant belt (Sanborn-Barrie and Skulski, 1999). Primary features (graded bedding, channel scours) within the Post Lake sedimentary rocks west of the map area young to the north.

Preliminary geochemical results for the Mountairy Lake amphibolite units ('A', Fig. 2) have flat rare-earth element (REE) primitive mantle-normalized profiles and depletion in Nb with respect to La and Th (Brown and Percival, 1999). Calc-alkaline and tholeiitic basalt flows from the Northeast Arm of Sturgeon Lake, possibly correlative with the central Sturgeon sequence, are geochemically similar (Sanborn-Barrie and Skulski, 1999) and support the observed along-strike continuity of units from the greenstone belt into the study area.

Plutonic rocks

Sheets of homogeneous, foliated granodiorite cut the supracrustal units. In the south, fine-grained foliated biotite granodiorite underlies a large area. In the north, medium- to coarse-grained, commonly K-feldspar porphyritic, hornblende-biotite granodiorite is present in the vicinity of Scruffy Lake. All units are cut by garnet-muscovite pegmatite which is massive to weakly foliated, and contains abundant supracrustal enclaves.

The southern structural panel is separated from the central panel by the northwest-trending Hilltop Creek fault (HCF, Fig. 2). A 100 m wide zone of steeply to moderately dipping cataclastic rock is exposed east of Mountairy Lake and along Hilltop Creek on the eastern limb of a north-trending fold (Fig. 3). The cataclasite contains angular fragments up to 10 cm in length of granite, amphibolite, exhalative sedimentary

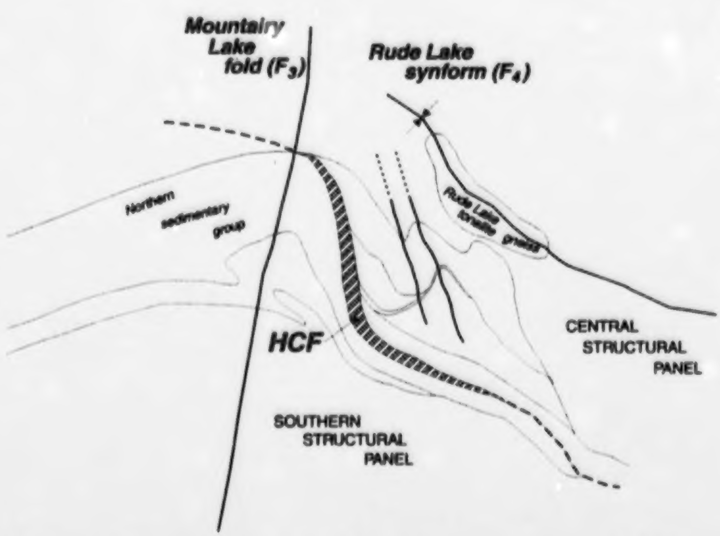

Figure 3. Sketch map showing the axial traces of map scale folds. HCF = Hilltop Creek fault. The Hilltop Creek fault separates the southern and central structural panels.

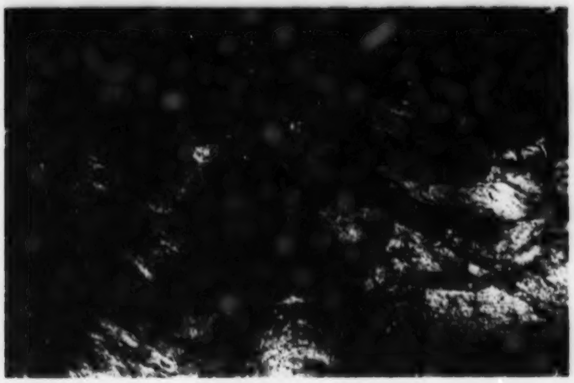

Figure 4. Cataclastic rocks from the north-trending portion of the Hilltop Creek fault. The north-south fabric (S_3) is overprinted by an east-west crenulation (F_4).

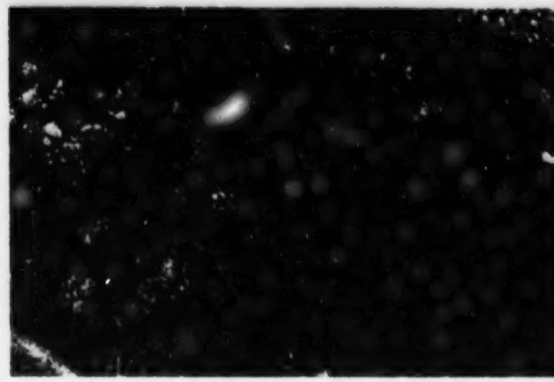

Figure 5. Metamorphic, randomly oriented hornblende crystals in a gabbro layered with mafic rocks of the Rude Lake package.

rocks, and silicate-facies iron-formation, set in a granular, fine-grained matrix with abundant chlorite, epidote, and hematite. Fragments of iron-formation are generally large, comprising entire outcrops, but cannot be followed along strike. Dykes of granite are the youngest component of the zone, and are also brecciated. Finely disseminated sulphide minerals occur throughout rocks of various origin within this unit.

The Hilltop Creek fault zone is curved at map scale from northwest- to north-trending, while at the outcrop scale, the cataclastic fabric is crenulated by small-scale, east-trending folds of probable D_4 generation (Fig. 4). Accordingly, the Hilltop Creek fault represents a zone of pre-D_4 brittle deformation which has been subsequently folded. It could represent a high-level expression of the D_3 Gunter Lake shear zone (Fig. 1), a ductile, dextral east-northeast-trending structure defined 20 km to the east, and overprinted by the Brightsand River shear zone in the present map area (Percival et al., 1999a). Older (D_1, D_2) shear zones have not been recognized. The cataclastic zone can be traced eastward through cover to some extent, where it separates the northern sedimentary package ('D', Fig. 2) from the Scruffy Lake supracrustal rocks ('E', Fig. 2) to the north. An open map-scale fold centered on Mountairy Lake (Fig. 3) plunges steeply north and affects bedding, S_3 foliation, and the Hilltop Creek fault. Its trend is at a high angle to regional D_4 structures and rocks on its eastern flank exhibit F_4 crenulations. Based on these observations, this unique fold is inferred to be late D_3 in age.

Central structural panel

Supracrustal rocks

Three main supracrustal units are present in the central panel. In the south, the Scruffy Lake unit ('E', Fig. 2) is dominated by fine- to medium-grained, mafic gneiss. It may be continuous with the fine-grained layered to gneissic amphibolite of the Brightsand River unit ('H', Fig. 2), on opposing limbs of a southeast-trending synform (Fig. 3). Pitted gabbroic dykes which cut the main S_3 foliation carry a mineral lineation typical of D_4 trend and plunge in both of these packages. A narrow, less than 25 m wide splay from the Hilltop Creek fault consists of a breccia of fine-grained amphibolite fragments within a fine-grained, granular mafic matrix separating the Scruffy Lake supracrustal unit from the Rude Lake sequence ('F', Fig. 2) to the north.

Mafic rocks of the Rude Lake unit ('F', Fig. 2) are lithologically and geochemically distinct from adjacent amphibolite bodies. The belt is up to 1.5 km thick, with primary volcanic features rarely preserved due to subsequent effects of alteration, metamorphism, and deformation. Sills of plagioclase porphyritic gabbro commonly contain garnet with retrograde plagioclase rims. Randomly oriented, acicular amphibole crystals in a plagioclase-rich matrix (Fig. 5) are sporadically developed through the Rude Lake amphibolite units. The north margin of the unit consists of metre-scale layering of mafic rocks and quartz-rich wacke. A felsic volcanic unit, 0.5 km thick, occurs in the southwest corner of the Rude Lake belt, where it is in gradational contact with mafic units. The felsic volcanic rocks are fine-grained biotite-muscovite-quartz-plagioclase rocks interlayered with pyritic exhalative and muscovite schist. The muscovite schist preserves tight, north-trending, chevron-type crenulations of an earlier (S_2 or possible bedding) fabric. Finely to coarsely disseminated sulphide minerals occur throughout the felsic rocks. To the south of the felsic volcanic unit, a narrow conglomeratic unit has rounded clasts up to 10 cm in length of granodiorite and volcanic rock types, as well as sandy beds of quartz-rich rock (Fig. 6A). The matrix varies compositionally from quartz-rich sandstone to wacke. Mafic dykes locally intrude along layering, and appear to replace the matrix. Strain varies considerably within this unit judging by clast elongation ratios; near the Hilltop Creek fault, clasts attain ratios greater than 10:1 (Fig. 6B). The southernmost unit within this package is mafic rocks resembling those in the northern mafic unit, although quartz-rich sedimentary and felsic volcanic rocks are not present.

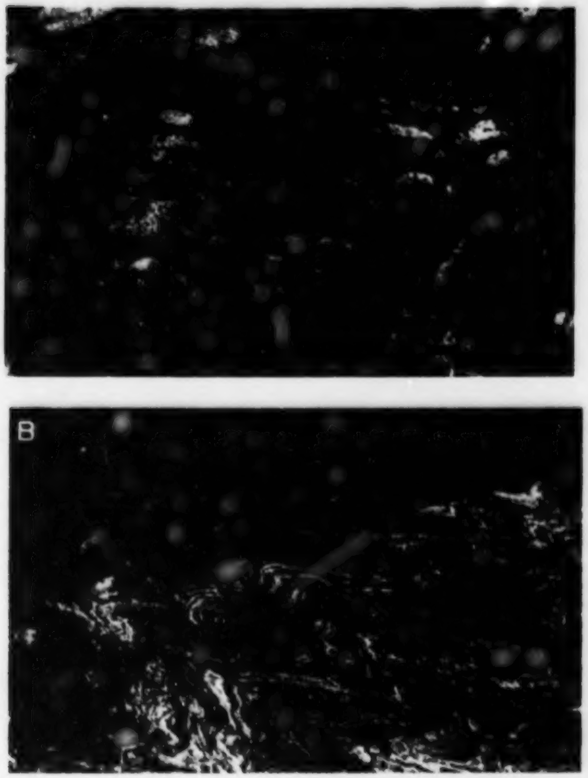

Figure 6. A) Conglomerate within the Rude Lake unit with ovoid granodiorite and quartz-rich clasts. B) Highly strained conglomerate in which clasts are stretched and folded.

Geochemistry of Scruffy Lake and Brightsand River amphibolite ('E' and 'H', Fig. 2) shows flat patterns (0.5–10x chondrites), most with negative Nb anomalies with respect to La and Th, and all have negative Ti anomalies relative to middle REEs (Brown and Percival, 1999). Two samples are also depleted in Th. Neodymium isotopic data from amphibolite of the Scruffy Lake unit yielded ε_{Nd} values of +0.8, +1.8, and +2.1; Brightsand River amphibolite rocks have values of +1.5, +1.8, and +2.7; and a sample of Rude Lake amphibolite gave a value of +2.4 (all at 2.73 Ga; K.Y. Tomlinson, unpub. data, 1999). Tholeiitic basaltic rocks of the Jutten group have similar geochemical profiles but lower ε_{Nd} values (Sanborn-Barrie and Skulski, 1999). The high positive ε_{Nd} values suggest predominantly depleted mantle sources, although the lowest values suggest the possibility of some older crustal reworking.

The Robert Lake belt ('I', Fig. 2) consists of mafic and sedimentary units exposed for a strike length of 15 km. Mafic rocks are fine-grained hornblende-plagioclase- clinopyroxene-garnet-epidote amphibolite with a well developed foliation. They are interlayered sporadically with plagioclase porphyritic gabbro, and rare coarse-grained ultramafic rock. Mafic rocks are associated along their entire strike length with psammitic to pelitic sedimentary rocks. Pelite contains garnet-sillimanite-biotite-muscovite- plagioclase-quartz and are locally migmatitic. Together with the mafic rocks, the assemblages indicate metamorphism to upper amphibolite facies. Compositional layering in units of sedimentary origin is interpreted to represent relict bedding, which is now parallel to the penetrative S_3 foliation. D_4 crenulation of this fabric is accompanied by a weak axial planar biotite foliation in fold hinges. Sulphide-rich zones (pyrite, pyrrhotite, chalcopyrite) are localized along the sedimentary schist-amphibolite contact. Within the amphibolite, a 10 m thick unit of silicate-facies iron-formation can be traced for 1 km in the Robert Lake area. Proprietary aeromagnetic data provided by Noranda Ltd. indicates that iron-formation within the Robert Lake unit extends from Hilltop Lake for 4 km eastward through Robert Lake. Preliminary geochemistry from a Robert Lake amphibolite shows no relative enrichment in rare-earth elements and negative Th anomalies (Brown and Percival, 1999). These characteristics are similar to tholeiitic basalt within the Beckington sequence of the Sturgeon belt which forms part of the diverse oceanic terrane (Sanborn-Barrie and Skulski, 1999).

Rude Lake tonalite gneiss (unit 'G', Fig. 2)

This complexly folded tonalite gneiss is a distinctive unit within the area, first described by Percival (1998, *see* Fig. 3 *in* Percival, 1998). It contains D_1 and D_2 structures which are preserved throughout this 3 km long lens. An S_1 gneissosity is folded into F_2 isoclines. Complex fold interference patterns, including doughnut-shaped domes and basins, result from overprinting by F_3 and F_4 folds. Mafic dykes are boudinaged and folded. Several generations of tonalite, granodiorite, and pegmatite are variably involved with the deformation. A complex chronology based on deformation events and crosscutting relationships has been established (Percival, 1998). Although the contact is cut out by pegmatite, an unconformable relationship between this unit and nearby quartz-rich sedimentary rocks in the Rude Lake supracrustal unit ('F', Fig. 2) may be supported by geochronology in progress.

Other plutonic units

Additional plutonic units of the central panel include sheets of tonalite, granodiorite, tonalite gneiss, and granite. Most of these units have a penetrative, steeply dipping, grain-scale S_3 foliation folded into open, east-trending F_4 folds. Tonalite gneiss is similar in structural style to amphibolite bands. A massive coarse-grained pyroxenite body, 0.5 km wide, is exposed west of the Brightsand River within tonalite gneiss ('L', Fig. 2). Xenolithic amphibolite units are present within tonalite gneiss and younger plutons. Fine- to medium-grained biotite tonalite carries an S_3 foliation and local quartz rodding lineation in the hinges of F_4 folds. Sills and dykes of tonalite occur within tonalite gneiss, commonly cutting the foliation at a low angle. Tonalite dykes also cut foliated, coarse-grained K-feldspar-porphyritic granodiorite. Granite and granodiorite dykes throughout this panel commonly carry a weak foliation oriented parallel to axial traces of F_4 folds. Dykes of muscovite granodiorite cut the S_3 fabric parallel to F_4 axial planes. One such dyke was sampled to provide an age

bracket between D_3 and D_4 events (Fig. 7). Late massive garnet-muscovite-bearing granite bodies occur as small plugs and dykes which cut all previously described units.

The Rude Lake supracrustal package ('F', Fig. 2) forms a broad, map-scale 'S' fold. Located on the eastern limb of the Mountairy Lake fold, this structure could be an F_3 parasitic fold (Fig. 3). These units are also located on the southern limb of a map-scale synform which links the Scruffy Lake ('E', Fig. 2) and Brightsand River units ('H', Fig. 2). The fold is open and upright in the west, becoming overturned and isoclinal toward the east.

Figure 7. Granodiorite dykes cutting the S_3 foliation axial planar to F_4 folds.

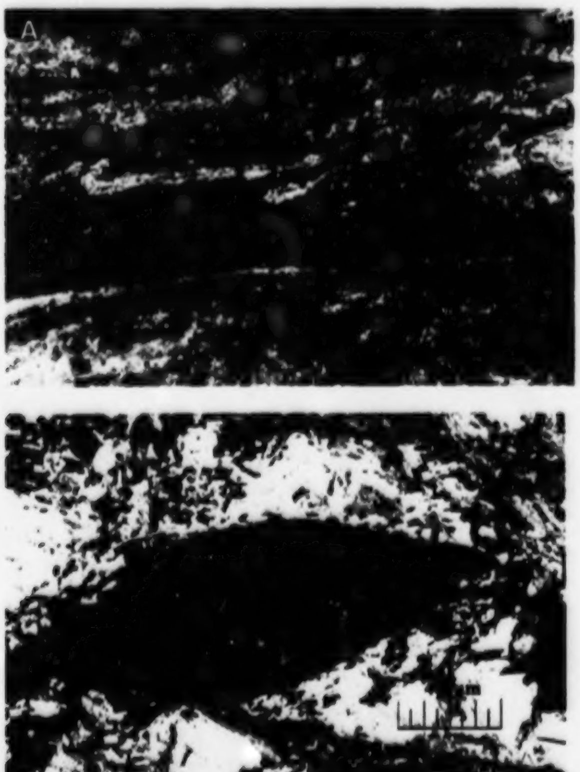

Figure 8. A) Ultramylonite from the Brightsand River shear zone. B) Photomicrograph of euhedral titanite crystals overgrowing annealed mylonitic fabric

The Robert Lake supracrustal belt ('I', Fig. 2) is bound along its northern flank by the west-northwest-trending Robert Lake fault (Fig. 2), which also separates the central and northern structural panels. Steep to moderate north-dipping structures are prominent along the strike length of the Robert Lake supracrustal belt. In several locations near Harmon Lake, this unit is in tectonic contact with granitoid units to the north. Such zones are characterized by steeply plunging folds, extensive epidote alteration, and local brecciation. Along the length of the Robert Lake supracrustal belt are east-northeast-trending, consistently moderately plunging mineral lineations. The structure resembles that of the ductile, sinistral D_4 Wapikamaiski Lake and Brightsand River shear zones (Percival et al., 1999a) although the lineation is steeper, possibly indicating a component of dip-slip shear. Ultramylonite at the margin of the Brightsand River shear zone contains euhedral, post-tectonic titanite crystals (Fig. 8A, B) whose age of 2677.5 ± 3 Ma (V. McNicoll, unpub. data, 1999) provides a minimum age of D_4 ductile deformation.

Northern structural panel

Supracrustal rocks

The northernmost panel is characterized by sparse, discontinuous amphibolite screens which appear to be the result of dismemberment by several generations of plutons. In some areas dominated by pegmatite, amphibolite units are traceable only as enclave-rich zones. The most prominent and continuous amphibolite is the 5 km long Stinson Lake unit ('J', Fig. 2) of medium-grained, foliated to gneissic hornblende-plagioclase± clinopyroxene rocks. This unit contains pods and layers of a distinctive coarse-grained pyroxenite with individual crystals up to 10 cm in size, associated with gabbroic layers containing nodular plagioclase phenocrysts. The northern amphibolite ('K', Fig. 2) is a homogeneous, medium-grained, mafic rock. Amphibolite units consist mainly of hornblende-plagioclase assemblages with accessory clinopyroxene, epidote, and rare garnet. Migmatitic layering is present locally, suggesting upper amphibolite facies.

Geochemical studies of the Stinson Lake amphibolite show no relative enrichment of REEs. Niobium is depleted in some rocks with respect to Th and La, while in others Th is depleted. All rocks are characterized by negative Ti anomalies with respect to middle REEs (Brown and Percival, 1999). Based solely on comparison of geochemical attributes, the Stinson Lake amphibolite could be correlative with Jutten tholeiitic volcanic rocks. The preliminary geochemical results from the northern amphibolite show a slight enrichment of LREE with respect to HREE, with negative Nb and Ti anomalies (Brown and Percival, 1999). Neodymium isotopic data for a single sample of the northern unit yielded an ε_{Nd} value of +2.1 (at 2.73 Ga, K.Y. Tomlinson, unpub. data, 1999), indicating a relatively depleted mantle source.

Plutonic units

The southern margin of the northern structural panel is dominated by tonalite gneiss in a 1.5 km wide straight zone. Mafic dykes are transposed into parallelism with the dominant foliation. Moderately east-plunging mineral lineations trend consistently at 070°. A xenolithic unit within this straight gneiss consists of dismembered mafic dykes which can be seen to cut the main fabric near the northern edge of the straight zone. One generation of tonalite gneiss cuts the mafic dykes, which in turn is cut by syn-D_4 granodiorite and unfoliated pegmatite. 'S' folds, sinistral offsets along late fractures and sinistral shear zones are all features of this unit. Toward the north is a body of coarse-grained, commonly hornblende-porphyritic, biotite-hornblende tonalite. It carries an S_2 foliation which is folded into close chevron-like F_3 folds accompanied by an axial planar S_3 foliation. The above units may correlate with the Harmon Lake gneiss (Percival et al., 1999a) exposed further to the northeast. Homogeneous, foliated, medium- to coarse-grained K-feldspar phorphyritic granodiorite and sheets of fine-grained biotite granodiorite cut tonalite gneiss. Dykes of fine- to medium-grained, massive to weakly foliated tonalite cut all previously described units. Granite and pegmatite bodies are massive to weakly foliated, and cut all units within this block.

The east-northeast-trending, sinistral Wapikamaiski Lake shear zone is a ductile D_4 feature (Percival et al. 1999a) which transects the northwestern corner of the map area (WLSZ, Fig. 2). Mylonitic tonalite gneiss units characterize this approximately 1 km wide zone.

LITHOPROBE seismic line 1D

The area was imaged as part of the 1997 phase of Western Superior LITHOPROBE seismic data acquisition. Four seconds (approximately 12 km) of migrated data for the northern end of line 1D are illustrated in Figure 9A, along with a corresponding cross-section (Fig. 9B) based on surface observations. Weak reflectivity characterizes the upper 1 second of the profile, consistent with moderate to steep (50° to >70°) dips of lithological units. At greater depth, broad antiformal reflections (e.g. 'C' and 'G', Fig. 9A) and smaller discrete reflective packages with gentle north and south apparent dips characterize the subsurface. Truncations of reflector groups can be used to define a set of through-going, moderately north-dipping trajectories to depths of at least 12 km, beneath which subhorizontal reflectors appear continuous. Although the definition of such trajectories is nonunique (vertical, steep-to-moderate north- or south-dipping trajectories are all

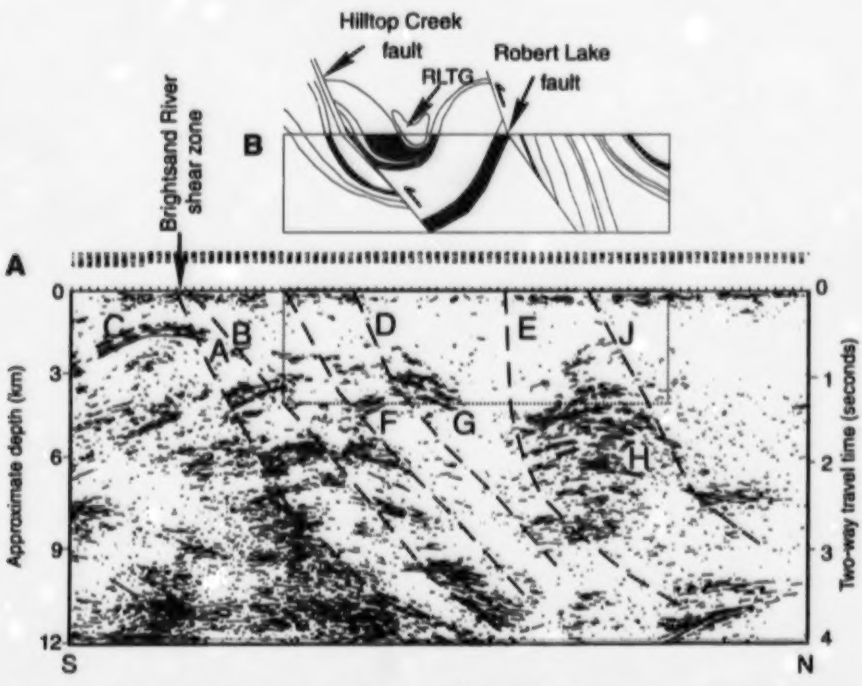

Figure 9. Interpreted seismic profile of northern Western Superior LITHOPROBE line 1D (see Fig. 2 for shot point locations) and corresponding geological cross-section; A) migrated section showing 30 km of data to four seconds. Vertical exaggeration caused by crooked line geometry is approximately 1.2:1. Labeled reflectors and truncations refer to features described in the text. Dashed box indicates position of geological cross-section B); B) geological cross-section based on the map presented in Figure 2. Amphibolite units (black) are shown as structural markers. RLTG = Rude Lake tonalite gneiss.

plausible), the steep northerly structural dip measured at the surface suggest these trajectories may correspond to steep north-dipping structures.

At the south end of the profile, a pair ('A', 'B') of prominent steeply north-dipping truncation trajectories project to the surface at the Brightsand River shear zone (Fig. 9A), which at the surface is a L>S tectonite with subhorizontal stretching lineations and subvertical foliation showing sinistral transcurrent displacement (Percival et al., 1999a). A northerly dip was not predicted from surface observations, however a near-surface reflective antiform ('C') is obviously truncated beneath the surface trace of the Brightsand zone. Shallow dipping, north- and south-trending trajectories are also possible for the Brightsand River shear zone (not shown). Additional parallel structures to the north ('D', 'E') project to the surface within the present map area (Fig. 2; 9B). The most prominent truncation ('D') separates two groups of shallow reflectors with opposing dips ('F', 'G'; Fig. 9A) and can be projected updip to the Hilltop Creek fault, which dips steeply (approximately 70°) to the north. Truncation trajectory 'E' separates a reflectivity antiform ('H') from reflective package 'G' to the south, and projects upward toward the north-dipping Robert Lake straight zone. Truncation 'J' within the northern panel, separates package 'H' from nonreflective crust to the north.

Although steep dips prohibit direct imaging of lithological units or faults, the seismic profiles provide control on the subsurface geometry of structural domains defined at the surface, as a stack of fault-bounded, north-dipping panels. Neither seismic marker units nor deflections into faults are apparent in the data, and therefore no control on the sense of vertical offset is available. Based on the seismic image alone, interpretations of normal, reverse, or transcurrent displacement could be applied.

DISCUSSION

D_1 and D_2 fabrics are present in only two units within the study area. The Rude Lake tonalite gneiss ('G', Fig. 2) and the coarse-grained tonalite body north of the Robert Lake fault ('M', Fig. 2) preserve evidence of penetrative ductile deformation prior to regional D_3 and D_4 events whose fabrics overprint the earlier structure. Most remaining units, including all supracrustal rocks, carry the S_3 foliation, and are affected by mesoscopic and map-scale F_4 folds.

It has been suggested that the Rude Lake tonalite gneiss is a piece of Mesoarchean crust that acted as depositional basement to the Rude Lake supracrustal package (Brown and Percival, 1999; Percival et al., 1999a). In this scenario, the stratigraphy would consist of platformal quartz-rich sediments overlain by basalt and felsic volcanic rocks. A structurally higher sequence of conglomerate and basaltic rocks may be depositional or a fault repetition of the underlying package.

Alternatively, complex structures within the Rude Lake tonalite gneiss may be the result of fold interference. Figure 9B shows the location of this unit within an F_4 synform. It is also located on the limb of the late D_3 north-trending Mountairy Lake fold. East-trending F_4 folds have produced dome-and-basin-like interference structures that characterize the gneiss, reflecting the ovoid shape of the unit in map view (Fig. 2). Still unexplained, however is the origin of S_1 gneissosity which is unique in the map area. Geochronology in progress may facilitate the interpretation of this unit.

The Hilltop Creek and Robert Lake faults link the Brightsand River and Wapikamaiski Lake shear zones, and subdivide the map area into sigmoidal structural panels in map view (Fig. 2). The 'Z' geometry of these panels is consistent with the sinistral shear sense of the two master structures. An increase in metamorphic grade from the southern to northern structural panels suggests a dip-slip component related to faulting, consistent with downdip lineations in the Robert Lake shear zone. Taking account of the seismically constrained geometry and offsets in metamorphic grade, the Hilltop Creek and Robert Lake structures are likely high-angle reverse faults. Reverse movement in a sinistral wrench zone implies a transpressive deformational regime ca. 2.68 Ga.

The interface between the central Wabigoon granite-gneiss complex and the western Wabigoon greenstone belt in the Brightsand forest area resembles the Winnipeg River–Wabigoon subprovince boundary zone in the Kenora area (cf. Melnyk et al., 1999). There, Mesoarchean crust of the Winnipeg River Subprovince (Beakhouse, 1991) was juxtaposed with juvenile Neoarchean supracrustal rocks of the western Wabigoon Subprovince, intruded by abundant sheets of plutonic material, and subsequently folded into upright structures. The intrusive and deformation chronologies match closely, both in relative and absolute age. It is possible that the two areas represent part of a continuous boundary zone that extends across the Miniss River fault (Sanborn-Barrie et al., 1999). In the Brightsand forest area, this boundary may be localized along the Hilltop Creek fault which separates rocks of oceanic affinity from more evolved rocks of continental affinity.

ACKNOWLEDGMENTS

Miriam Campbell is thanked for excellent field assistance. The Ontario Ministry of Natural Resources granted access to restricted and closed roads. Noranda Ltd. provided unpublished detailed aeromagnetic data and reports. Financial support through a LITHOPROBE grant to J.A. Percival is greatly appreciated. M. Sanborn-Barrie provided useful insight prior to and during the summer, as well as a thorough, critical review of this paper. M. St-Onge's editorial comments improved the presentation. LITHOPROBE contribution no. 1124.

REFERENCES

Beakhouse, G.P.
1991: Winnipeg River Subprovince; *in* Geology of Ontario; Ontario Geological Survey, Special Volume 4, Part 1, p. 279–302.

Blackburn, C.E., Johns, G.W., Ayer, J.L, and Davis, D.W.
1991: Wabigoon Subprovince; *in* Geology of Ontario; Ontario Geological Survey, Special Volume 4, Part 1, p. 303–381.

Brown J.L. and Percival J.A.
1999: Greenstone-granite contact relationships at the southeastern sturgeon belt margin, western Superior Province, Ontario; *in* 1999 Western Superior Transect Fifth Annual Workshop, (ed.) R.M. Harrap and H.H. Helmstaedt; LITHOPROBE report #70, LITHOPROBE Secretariat, University of British Columbia, p. 20–22.

Melnyk, M.J., Scott, D., and Cruden, A.R.
1999: Structure and relative timing of deformation in the Lake of the Woods greenstone belt, Wabigoon Subprovince; *in* 1999 Western Superior Transect Fifth Annual Workshop, (ed.) R.M. Harrap and H.H. Helmstaedt; LITHOPROBE report #70, LITHOPROBE Secretariat, University of British Columbia, p. 40–47.

Percival, J.A.
1998: Structural transect of the central Wabigoon subprovince between the Sturgeon Lake and Obonga Lake greenstone belts; *in* Current Research 1998-C; Geological Survey of Canada, p. 127–136.

Percival, J.A., Castonguay, S., Whalen, J.B., Brown, J.L., McNicoll, V., and Harris, J.R.
1999a: Geology of the central Wabigoon region in the Sturgeon Lake-Obonga Lake corridor, Ontario *in* Current Research 1999-C; Geological Survey of Canada, p. 197–208.

Percival, J.A., McNicoll, V., Whalen, J.B., Castonguay, S., Brown, J.L., and Harris, J.R.
1999b: Tectonomagmatic evolution of the central Wabigoon region in the Sturgeon Lake - Obonga Lake corridor; Geological Association of Canada Abstracts, v. 24, p. 98.

Rogers, D.P.
1964: Metionga Lake area; Ontario Department of Mines, Geological Report 24, 53 p.

Sanborn-Barrie, M. and Skulski, T.
1999: Tectonic assembly of continental margin and oceanic terranes at 2.7 Ga in the Savant Lake-Sturgeon Lake greenstone belt, Ontario; *in* Current Research 1999-C; Geological Survey of Canada, p. 209–220.

Sanborn-Barrie, M., Skulski, T., Percival, J.A., Stott, G.M., Tomlinson, K.Y., and Davis, D.W.
1999: A suture zone within the Savant-Sturgeon greenstone belt and implications for a pan-Wabigoon superterrane boundary; Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting Sudbury 1999, Abstract Volume 24, p. 108

Trowell, N.F.
1983: Geology of the Sturgeon Lake area; Ontario Geological Survey, Report 221, 97 p.

Geological Survey of Canada Project 970014